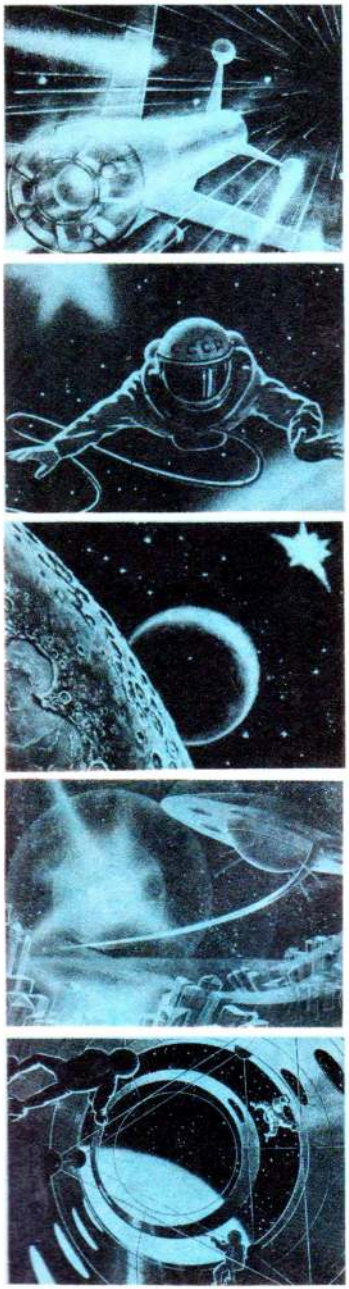
SOVIET SPACE RESEARCH

"Soviet artificial Earth satellites have provided a reliable bridge between the Earth and outer space. The way to the stars has been opened!"

"New, more advanced satellites and space rockets will undoubtedly be developed as well as automated space probes and habitable interplanetary stations, and other planets will eventually be reached."

Sergei Korolev,
Chief Designer
of Spacecraft
(1906 to 1966)

Novsti Press
Agency Publishing
House
Moscow, 1972

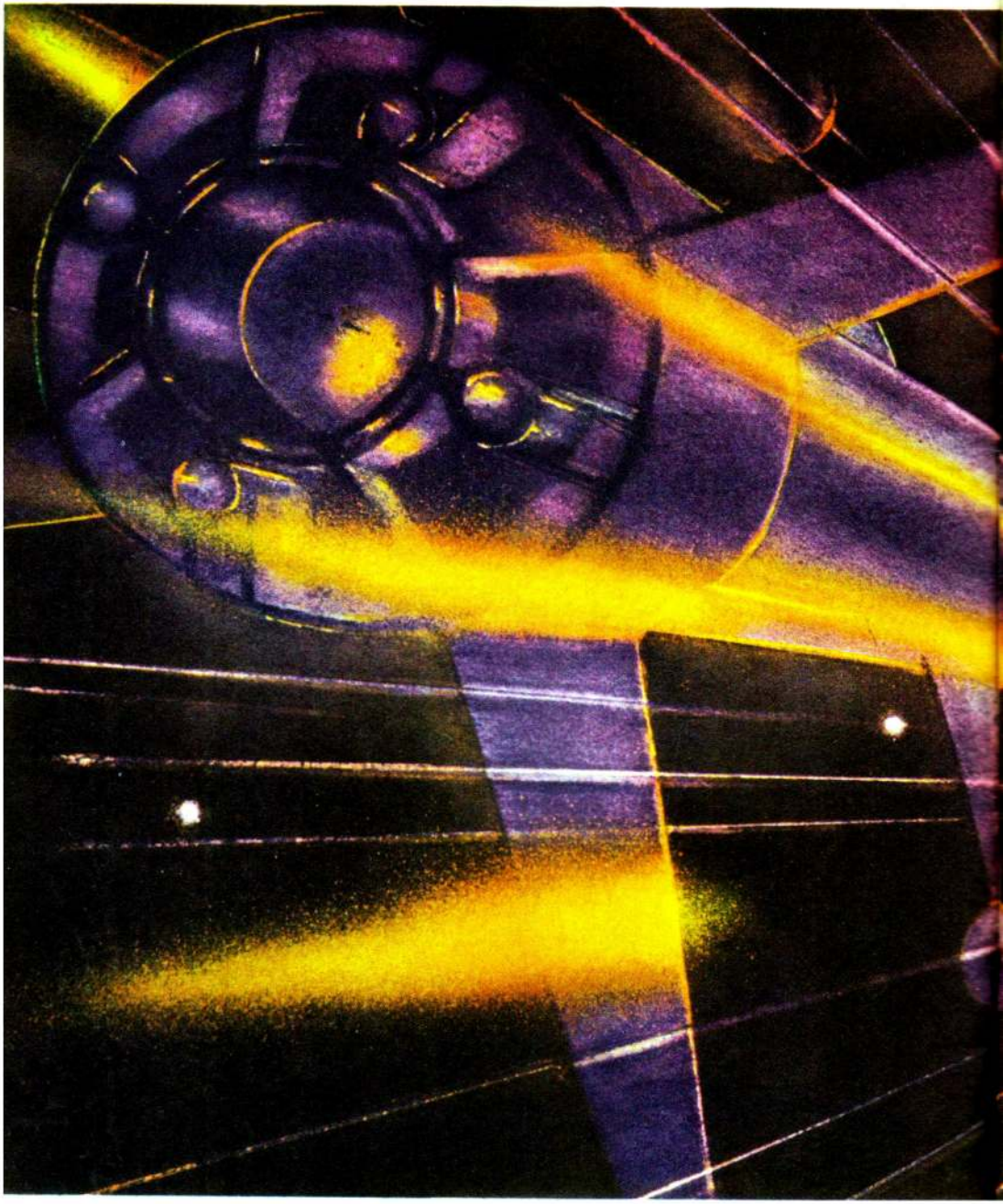


SOVIET SPACE RESEARCH

A hearty welcome to cosmonauts back from their mission has become traditional. Muscovites cheering the crews of the *Soyuz-6*, *Soyuz-7* and *Soyuz-8* in October 1969

We are living in the middle of the second decade of the space era. Increasingly the sky is pierced by carrier rockets as automatic space probes start on their way. Daring cosmonauts fly planetary missions and robot scouts of the Universe set out on their journeys to faraway worlds as man continues his exploration of outer space.

All of this is accepted as a part of our life today, of our continuing development. The confines of the Earth have become too narrow to contain man's questing spirit as his thoughts travel cosmic worlds, eager to



fathom the ultimate secrets of the universe.

A mere fifteen years have passed since October 4, 1957, when the "beep-beeps" of the Soviet Sputnik heralded the dawn of the space era. Today, the number of craft that have been or still are in space exceeds one thousand, with the Soviet Union's contribution nearing six hundred.

At first something to marvel at, the practical importance of space exploration is now recognized by all. Already six nations—the USSR, the United States, France, Britain, Japan and China—are capable of launching satellites of their own, and many countries are engaged in space research. But the tasks of this research are so formidable and numerous that it is impracticable for any one country to attempt to tackle them all single-handed. Progress in the field of space exploration will clearly be greatly accelerated given close international co-operation.

Ever since the first Sputnik outer space exploration has not been an end in itself; every Soviet experiment in space has been part of a programme of research in the interests of terrestrial sciences and the national economy. It is hard to find a sphere of human endeavour which is not beneficially influenced by space research, be it meteorology or biology, climatology or medicine, geodesy or television, geology or radio communication, astronomy or hydrology, physics or metallurgy.

Already, we have travelled a long way—from the first man-made satellite of the Earth and the first man in space to lunar expeditions and manned orbital laboratories.

The USSR can justly pride itself on its pioneering role in the conquest of space. Systematically carrying out its programme of piloted and automatic flights, the Soviet Union has achieved a series of spectacular "firsts", among them the first artificial satellite of the Earth, the first manned space flight, the first Moon probes and photographs of the far side of the moon, walking in space, spaceship rendezvous and the first experimental station in orbit, the first soft-landing on the lunar surface, the first

The Presidium of the USSR Academy of Sciences

automatic delivery and automatic selection and return to earth of lunar rock samples, the first lunar robot, and the first soft landings on Venus and Mars.

The Soviet space programme is concentrated in three main directions:

near-space research;

detailed investigation of the Moon and circumlunar space;

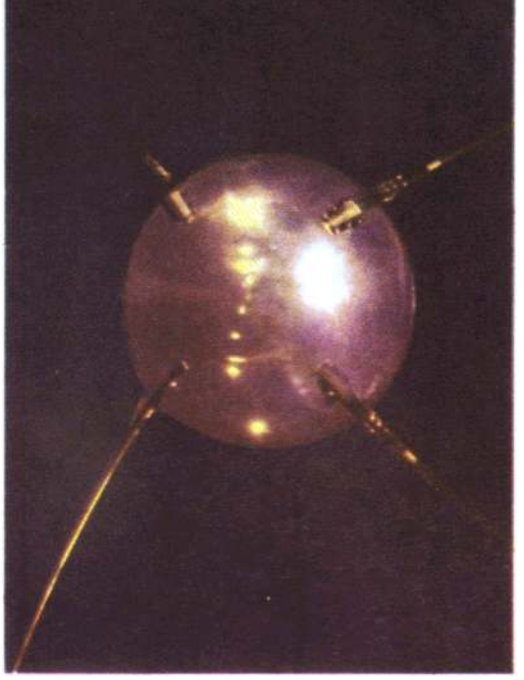
study of the planets of the solar system.

For this, three groups of apparatus are used: automatic or piloted satellites of the Earth, automatic vehicles for research on the Moon, or orbiting stations for working in space near it, and automatic interplanetary probes with or without landing capsules, whose missions may differ substantially. Yet, sometimes their missions partially or fully coincide.

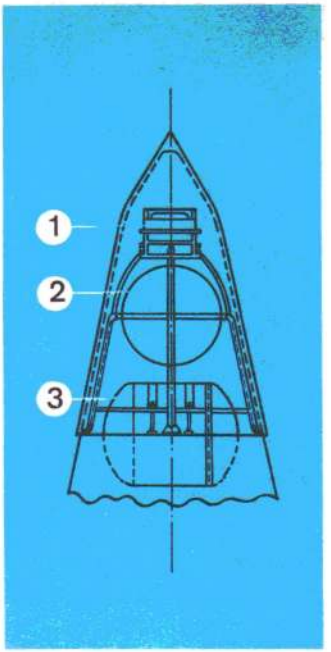
Most research and experimentation are concentrated on circumterrestrial space because of the immediate practical returns they provide and because it is possible, with the help of relatively simple means, to test new technical equipment and determine ways of further development of space engineering, and trends of research, in deep space. Among the automatic devices used to serve the interests of science and the economy are the *Molniya* communication satellites with the extensive *Orbita* system of receiving stations, the weather satellites of the *Meteor* series whose information is used, in some way or other, by all countries, and the *Kosmos* satellites, of which there will soon be 500.

In the field of manned flights, the main trend of development of Soviet cosmonautics is for the establishment of lasting stations with crew rotation. The entire Soviet man-in-space programme has been directed towards achieving this objective. Already the work of *Salyut*, the first piloted orbital scientific station, has demonstrated the possibilities that this approach opens up.

A very important place in the Soviet space programme is occupied by the investigation of the Moon and lunar environs. The study of the earth's satellite helps towards



The first artificial Earth satellite

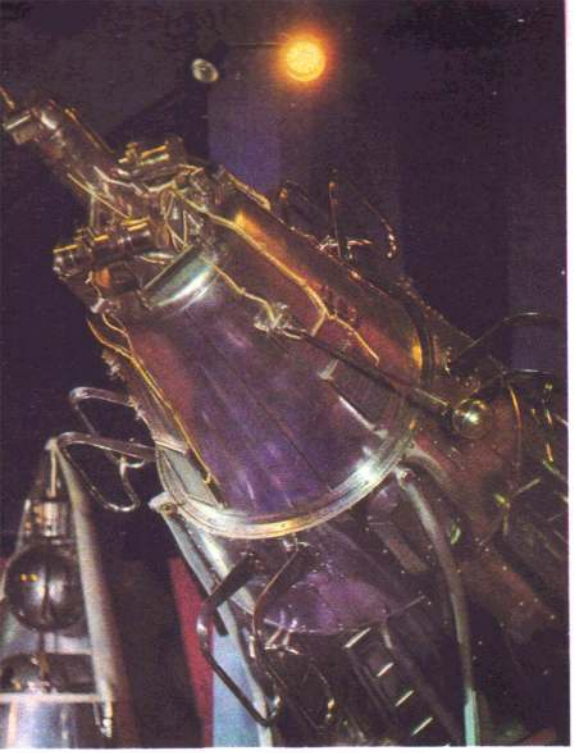


The second satellite and its instrumentation:
1) Radiation meter.
2) Container with radio equipment.
3) Air-tight capsule with a dog

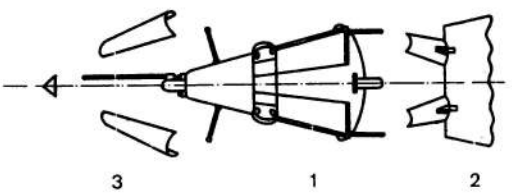
obtaining a better understanding of the processes taking place in the Universe and adds to our knowledge of our own home, the Earth. The lunar programme has advanced all the way from the first space rocket sent towards the Moon, to *Luna-16* and *Luna-20*, which returned lunar rock samples, and the most recent experiment—the self-propelled laboratory *Lunokhod-1*. which worked on the lunar surface for more than ten months.

The Soviet programme also includes exploration of the planets of the solar system nearest to us. The flights of the *Venera* series of interplanetary automatic probes were crowned with the successful landing on the surface of Venus of the probe *Venera-8* which for fifty minutes telemetered back valuable information. The *Mars-2* and *Mars-3* probes are still working. The descent module of *Mars-3* accomplished a soft touch-down on the planet.

Practical returns from the exploration of the planets and the Moon are still difficult to assess. We will have to wait till a later stage. The world's first cosmonaut, Yuri Gagarin, said that the penetration into outer space cannot be viewed only through the prism of day-to-day interests and current practice, and that if throughout the history of their existence men were concerned only with satisfying their immediate needs, mankind would probably still be living in caves.



The third Earth satellite



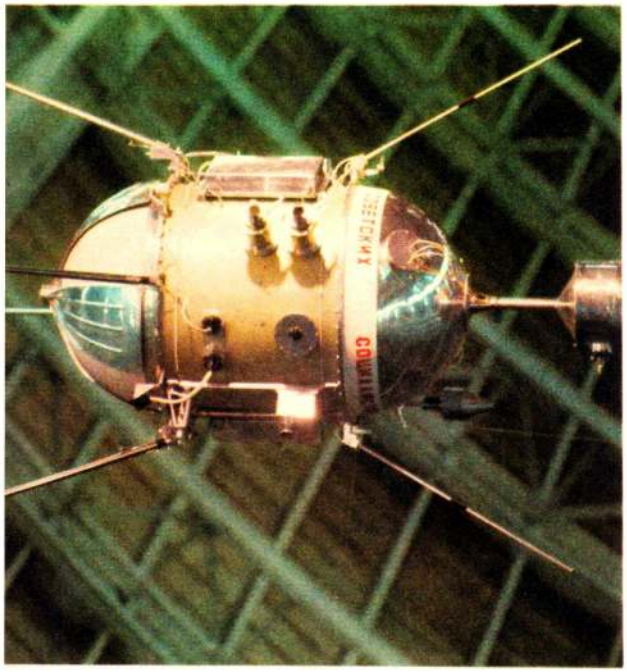
Schematic drawing showing the separation of the third satellite from the carrier rocket:
1) satellite;
2) carrier rocket;
3) detachable protective cone

EARTH ORBITERS

The world's first artificial Earth satellite went into orbit on October 4, 1957. Despite its seeming simplicity, the first Sputnik represented a tremendous amount of work done by teams of scientists and engineers, it embodied the whole creative heritage of Soviet and foreign science. Its flight was a supreme test of all principles of cosmonautics.

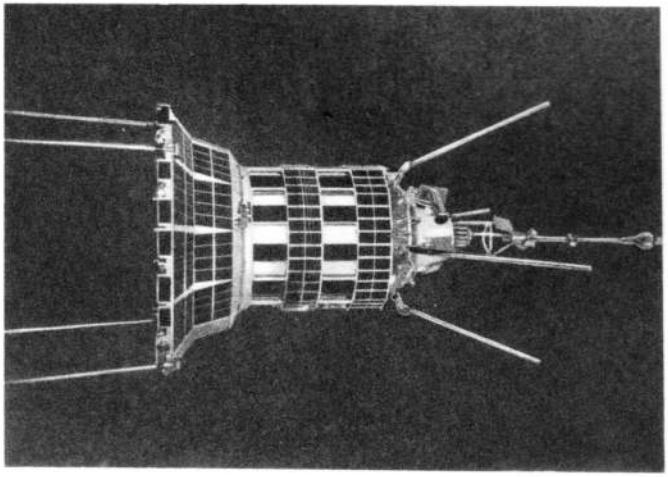
The launching of *Sputnik-1* was a milestone in man's exploration of the universe around him. It marked the first step of his release from earthly ties. In addition to confirming the possibility of space flights, the first *Sputnik* yielded valuable scientific information. For the first time, it became possible to measure the density of the upper layers of the atmosphere and to obtain data about the propagation of radio waves in the ionosphere, and similar physical information.

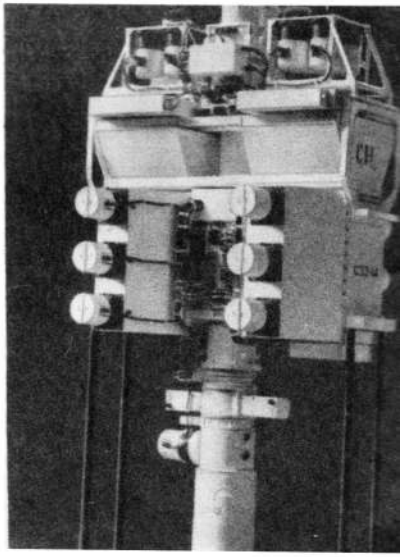
It was clear from the outset that sooner or later space experiments conducted directly by man would become indispen-

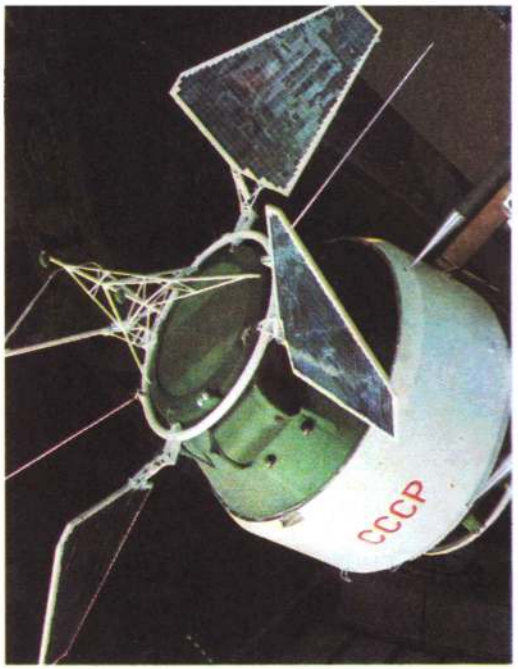


A satellite of the *Kosmos* series

The *Elektron-2* satellite







The *Proton* satellite

Research equipment of the *Proton* satellite

sable. Long and painstaking preparation followed involving, first and foremost, investigation of the influence of space flight factors on the living organism. On November 3, 1957, *Sputnik-2* became the world's first biological satellite. It carried a test animal, the dog Laika, in a pressurized compartment. *Sputnik-2* yielded the first scientific data on the behaviour of a living organism in space flight conditions.

The third Soviet satellite was equipped with a whole range of scientific instruments and carried out an extensive research programme which included measurements of the density and composition of the upper atmosphere, the concentration of charged particles, cosmic rays, magnetic and electrostatic fields, meteoric particles, etc. The data thus gained pointed to the existence of an outer radiation belt round the Earth.

With every successive launching flight programmes grew in complexity and the working life of satellites was extended. Most of the satellites performed a double function, serving the interests of both pure and applied sciences.

An extensive and varied programme of space research of a fundamental as well as applied character was commenced on March 16, 1962 with the *Kosmos* series. At present the number of *Kosmos* launchings is close to 500. The orbits of these satellites have different inclinations and range in altitude from 145 to 60,000 kilometres.

Despite their great diversity the tasks carried out by the *Kosmos* satellites can be put into several principal groups:

— study of the upper atmosphere and of physical phenomena in outer space and of their interconnection;

— biological experiments;

— solution of technical problems connected with space flights, development of structural elements and on-board equipment of space vehicles.

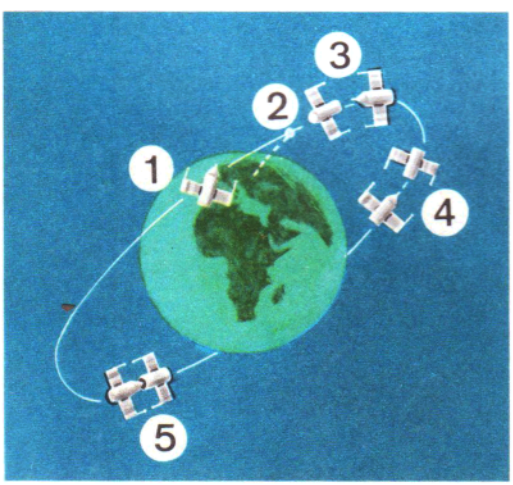
The *Kosmos* satellites study the structure of the ionosphere and the earth's magnetic field, meteoric particles and cosmic rays, measure the natural radiation of the Earth and help solve problems of terrestrial and space radio communication, monitor radiation levels during piloted flights, and so on.

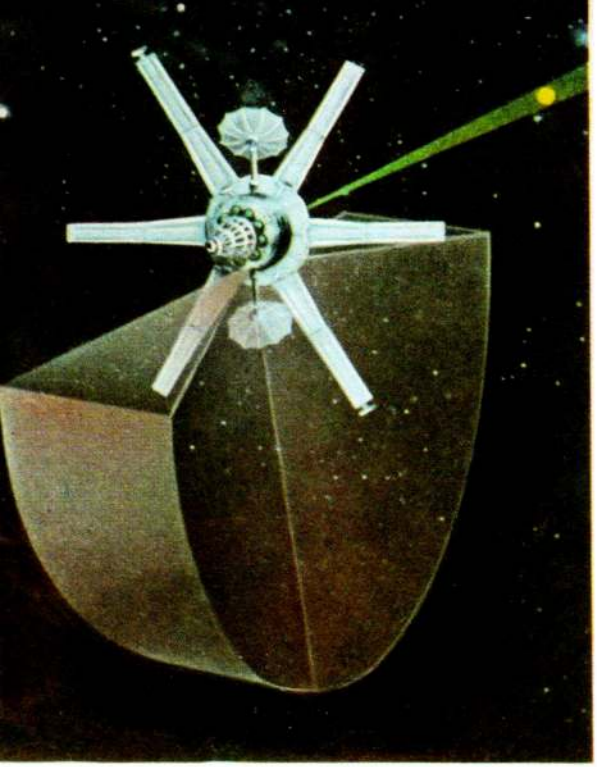
Biological experiments study in detail the influence of space flight conditions on the living organism, knowledge of which is indispensable to planning manned flights. As part of this programme *Kosmos-110* carried two dogs which were returned to earth after 22 days in orbit.

The *Kosmos* satellites (Nos. 186 and 188, 212 and 213) were used in practicing automatic rendezvous and docking, which is necessary for the assembly of large orbital stations. Devices for meteorological observations were also developed with the help of *Kosmos* satellites some of which have been working successfully in the *Meteor* system of space weather observation.

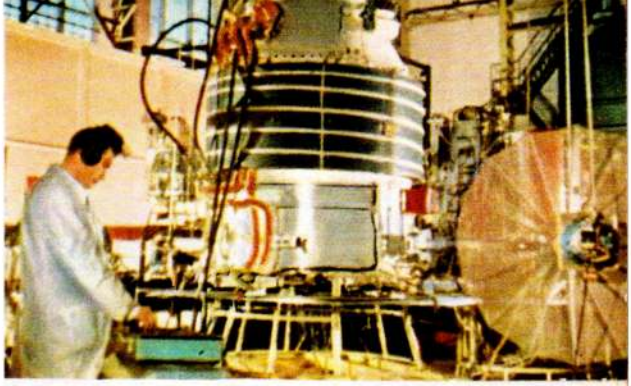
Depending on the programme of research, recoverable *Kosmos* satellites are used to bring the results of experiments back to earth. In other experiments three, five and even eight satellites have been injected into varying orbits by a single carrier rocket. This affords considerable savings in the

Automatic docking of the *Kosmos-213* and *Kosmos-212* satellites:
1) The *Kosmos-212* before the launching of the *Kosmos-213*
2) The point of insertion of the *Kosmos-213*
3) Rendezvous
4) Docking
5) Mating

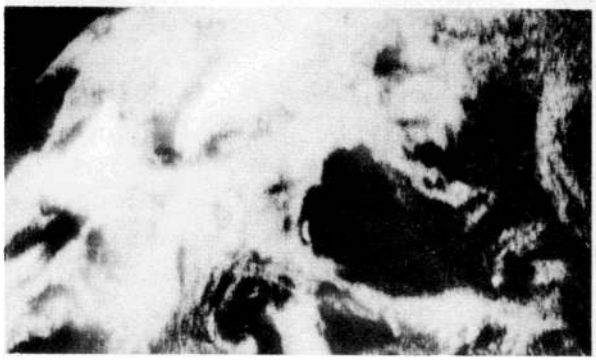




Orienting *Molniya-1* satellite to the Sun and the Earth



Equipment of the *Molniya-1* relay satellite being tested



A shot flashed by the *Molniya-1* relay satellite

cost of space exploration. In addition, since most of the *Kosmos* satellites are of standard design, have similar on-board service systems, and their instrumentation can be changed without much difficulty to suit different purposes, their serial production can be organized. Together with the use of standard-type carrier rockets, this results in an appreciable economy.

Besides the *Kosmos* series, special-purpose satellites are launched. Two systems of *Elektron* satellites, developed in 1964, yielded much new data on the Earth's radiation belts and magnetic field and led

to the discovery of a number of heretofore unknown physical phenomena in near space.

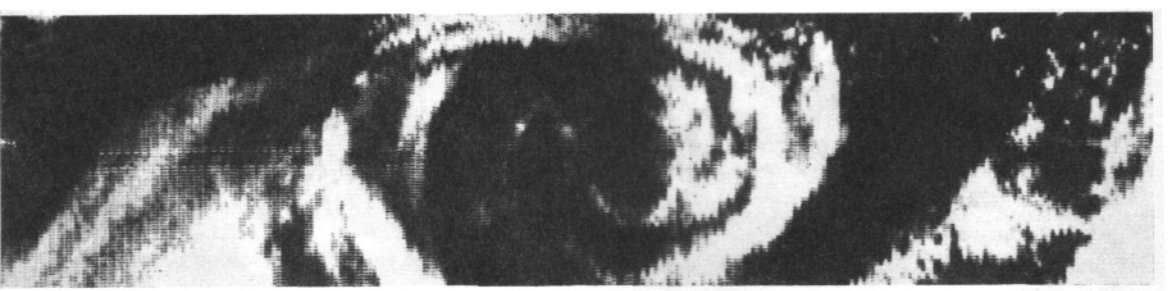
The *Polyot-1* and *Polyot-2* satellites, launched in 1963 and 1964 respectively, were the first manoeuverable space vehicles. They carried propulsion systems by means of which they could change orbit altitudes and inclinations.

Outer space is of the greatest interest to physicists. Between 1965 and 1968 the Soviet Union launched four heavy *Proton* satellites equipped to study cosmic rays and the behaviour of particles with super-high energies which cannot be developed yet even by the most powerful of earth-based accelerators. The last of this series, *Proton-4*, weighed 17 tons. Their programme included the study of the energy spectrum and chemical composition of primary cosmic ray particles and the energy spectrum and intensity of gamma rays and electrons of galactic origin.

An immediate practical use of space is the day-to-day work done by satellites in communication and meteorological systems.

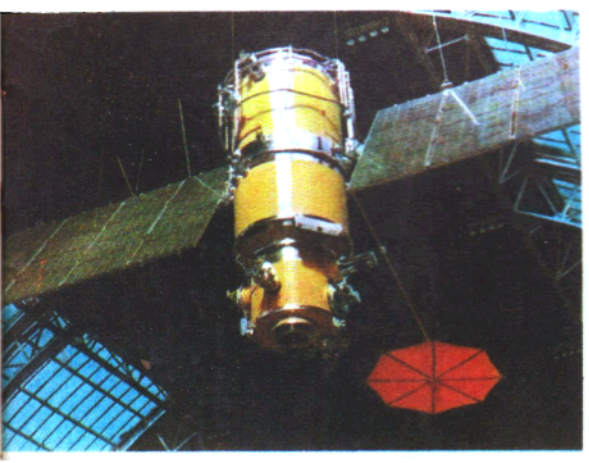
Since 1965 the Soviet Union has operated

A cyclone photographed by the *Kosmos-144*



the *Orbita* long-range radio communication system, using satellites of the *Molniya-1* and *Molniya-2* series and transceiver stations situated in different parts of the country and in the Mongolian People's Republic. Choosing the necessary inclination and other parameters of orbits, and using the possibility of consecutive activation of several *Molniya* satellites, the *Orbita* can ensure round-the-clock relaying of telecasts and two-way telephone, telegraphic and phototelegraphic communication. In the case of meteorology, since May 1966 *Molniya* satellites have been transmitting TV pictures of the Earth from altitudes of 30,000 to 40,000 km, showing the distribution of clouds over the Northern Hemisphere.

The meteorological system *Meteor*, based on *Kosmos* and *Meteor* weather satellites, collects information for day-to-day weather forecasting and for research purposes. Data obtained with its help appreciably raise the reliability of forecasts and make it possible to detect cyclones and hurricanes, choose optimal marine routes, establish the boundaries of the ice cap in the polar regions, etc.



The *Meteor* weather satellite

СССР

PILOTED SPACESHIPS

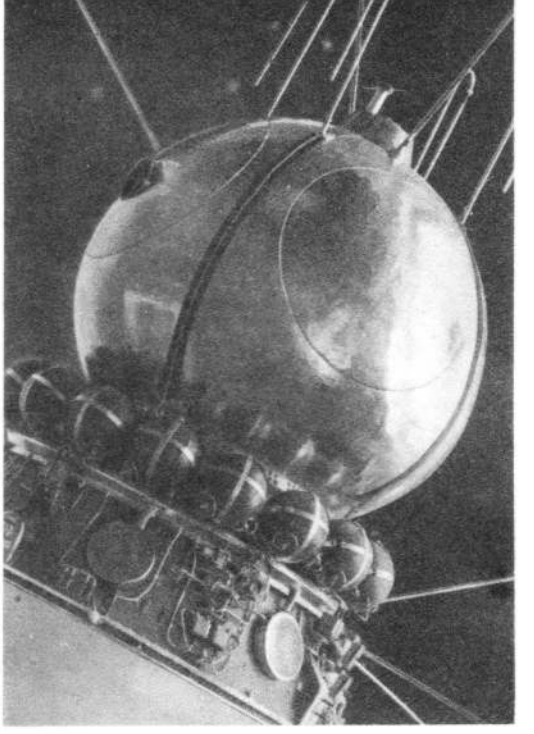
Automatic devices are doing invaluable work in outer space exploration. Cosmonautics is becoming one of the most effective instruments of extending human knowledge. And yet it is obvious that no automation, however "clever", no machine, no matter how sophisticated, can replace man with his capacity for instant intervention in the work of equipment and in the selection of information, quick sizing up of complex, often unforeseeable situations and adoption of correct decisions, and emotional perception of reality. The effec-

First Cosmonaut Yuri Alexeyevich Gagarin and Chief Spacecraft Designer Sergei Pavlovich Korolev

tiveness of a space vehicle carrying out a multipurpose programme of research rises considerably if there is a man around.

The first manned flight, as the launching of the first satellite, was preceded by a tremendous amount of hard work by Soviet scientists. With the aid of satellites, methods had to be tested of placing spaceships in the required orbits, of orienting and stabilizing them in space, of supplying them with electric power and maintaining communication with them. Intricate yet highly reliable life-support equipment, systems ensuring safe return through the atmosphere and landing of the cosmonauts had to be developed, and so on. All these tasks were carried out in 1961 and 1962 in the course of experiments with five spaceships.

The *Vostok* carrier rocket



The *Vostok* spaceship

The efficiency of the systems was verified using test animals. The flights of the last two satellite ships were programmed so as to rehearse the first piloted flight. After orbiting the Earth they landed safely in the assigned region of the Soviet Union. The door to space travel was open.

On April 12, 1961 mankind's millennia-old dream came true as the Columbus of the

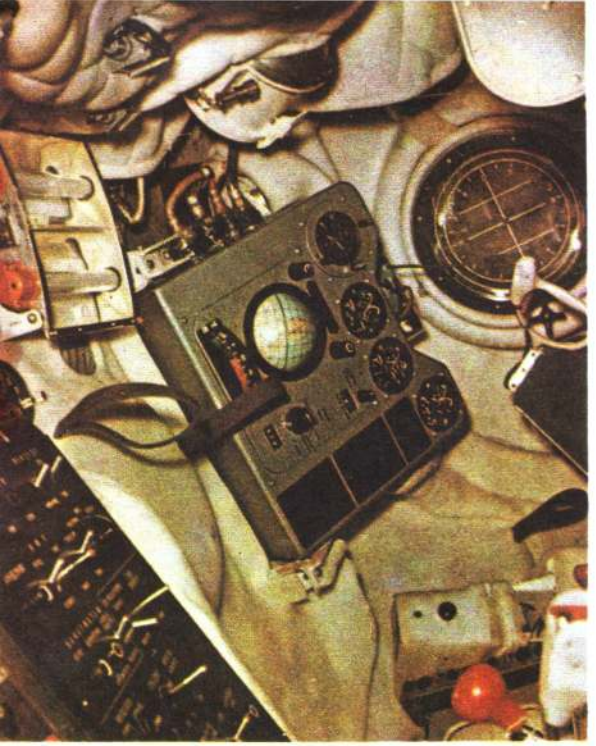
Universe, Yuri Gagarin, made his legendary turn around the Earth aboard the Soviet spaceship *Vostok*. By this flight, a new chapter was opened in man's history.

The *Vostok* consisted of two principal elements: the recoverable capsule and the instrument compartment. It weighed 4.73 tons. The spherical capsule had a diameter of 2,3 metres and weighed 2.4 tons. The cosmonaut, wearing a space suit, lay in an ejector seat. The vehicle could be controlled by the cosmonaut as well as automatically. The life-support system, designed to function for ten days, maintained normal ambient conditions (air temperature, pressure, composition, etc.) throughout the duration of the flight. Other equipment included radio communication means and apparatus for telemetric observation of the state of the cosmonaut and the ship's systems. Prior to descent the spaceship was oriented in space, following which the retro-engine was fired, slowing down the ship's velocity for going into the descent trajectory. Then the capsule separated, and after self-braking in the denser atmosphere the last stage of descent was by parachute. Finally, the cosmonaut was able to choose whether to remain in the cabin or whether to eject and parachute independently.

Between 1961 and 1963, six Soviet cosmonauts made space flights under the *Vostok* programme. Besides Yuri Gagarin they were Herman Titov, Andriyan Nikolayev, Pavel Popovich, Valery Bykovsky and Valentina Tereshkova. The programme featured prolonged solo and group flights lasting several days by way of preparation for the establishment of orbital stations. In the course of the flights, which were of different duration tests were carried out to determine the capabilities of the cosmonauts in piloting the ship and conducting experiments while in orbit, as well as to assess man's ability to withstand longer periods in space. The *Vostok* programme became the basis for the further development of Soviet cosmonautics. The *Vostok* flights also tested the adequacy of their design and systems and the teamwork of all the personnel involved in control and monitoring and in the search and rescue organizations.

One conclusion drawn from the *Vostok* programme was that a single cosmonaut would not be able to carry out the extensive and varied programmes planned for future launchings. A new, multiseat spaceship, the *Voskhod,* was developed. As distinct from the *Vostok*, it had a powered soft-landing system, an additional, or reserve retro-engine, new instrumentation and an air lock-chamber so that it would be possible to leave the spacecraft and enter into outer space.

The *Voskhod* was the first space laboratory. Two flights were performed in ships of this type. The crew of *Voskhod-1,* ship commander Vladimir Komarov, Konstantin Feoktistov, a scientist, and Boris Yegorov, a doctor, carried out an extensive programme of scientific and technical research and performed biomedical experiments. Then, with the flight of *Voskhod-2,* commanded by Pavel Belyayev, Alexei Leonov, on March 18, 1965, performed his epoch-making walk in space, proving that man,



Cabin of the *Vostok* spaceship

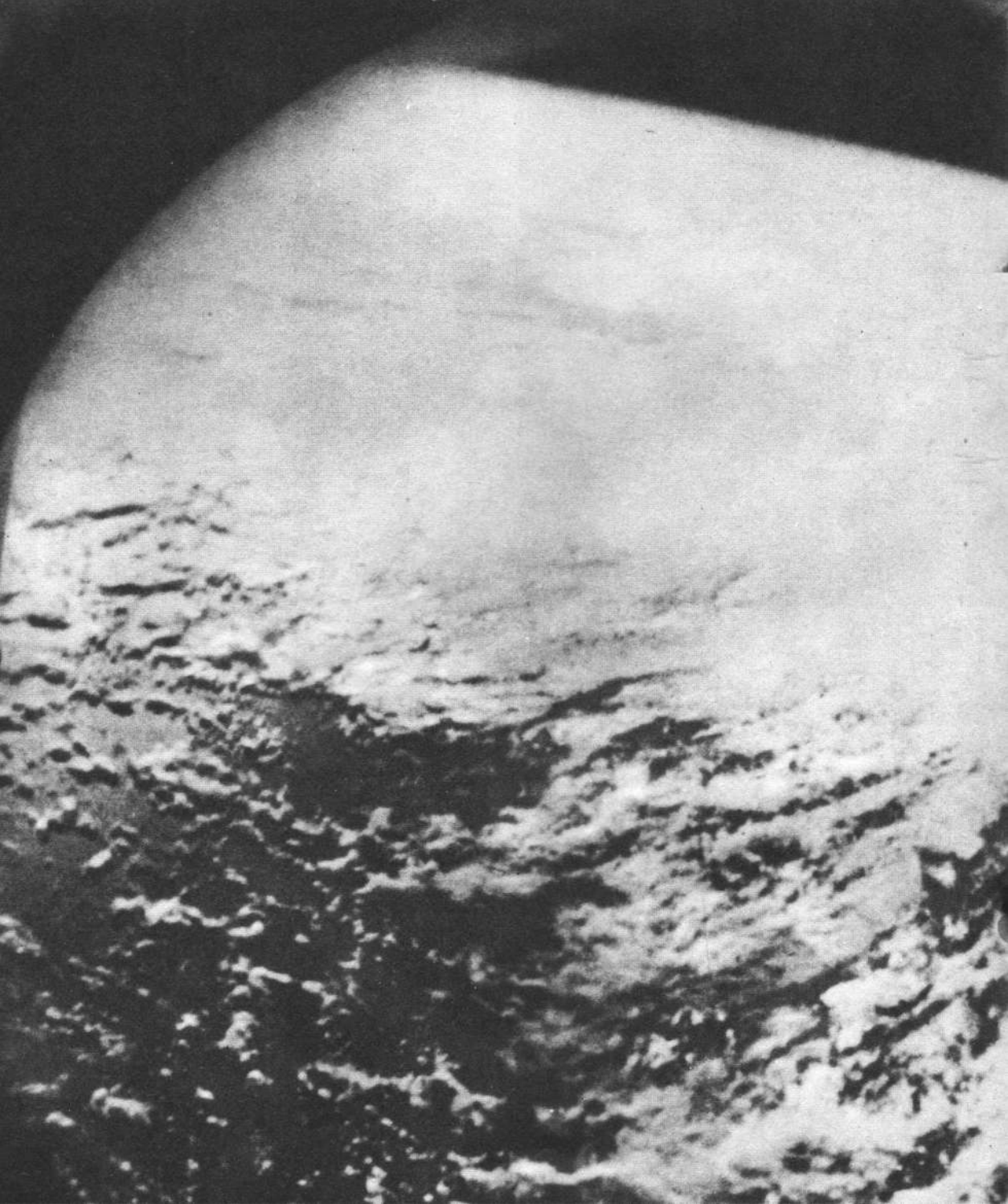
Discussing German Titov's training flight in a jet fighter

Valery Bykovsky after a training parachute jump

using an autonomous life-support system, could step out of a spaceship and move freely in outer space, carry out technical operations and make scientific observations.

The *Voskhod* flights indicated the direction to be taken in future for carrying out a large-scale programme of scientific and technical research in outer space and establishing long-duration orbital stations.

Next came the flights of the multiseater and multi-purpose *Soyuz* ships, which differed from their predecessors in being more comfortable, better adapted for long flights, more manoeuverable, and capable of controlled descent re-entry with the use of aerodynamic quality. They are equipped with systems for mutual search, approach and docking and for carrying out a large number of technical and scientific observations.



Valentina Nikolayeva-Tereshkova, the first woman-cosmonaut, before going into space

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The first picture taken from space by German Titov

A *Soyuz* ship consists of the following principal sections: the crew cabin. the orbital compartment and the instrument-and-systems compartment. The cabin is in the centre. In front is the orbital compartment with a docking device. Attached to the tail end of the ship are panels of solar batteries, totalling 14 square metres in area. The internal volume of the cabin and the orbital compartment is 9 cubic metres. The orbital compartment is designed for scientific observations and investigations, for rest and recreation, and has a lock providing for emergence into space. The ships are equipped with a liquid-propellant rocket-engine for manoeuvering in orbit and descent. There is also a system of low-thrust vernier engines for fine positioning.

Between 1967 and 1971 eleven *Soyuz*

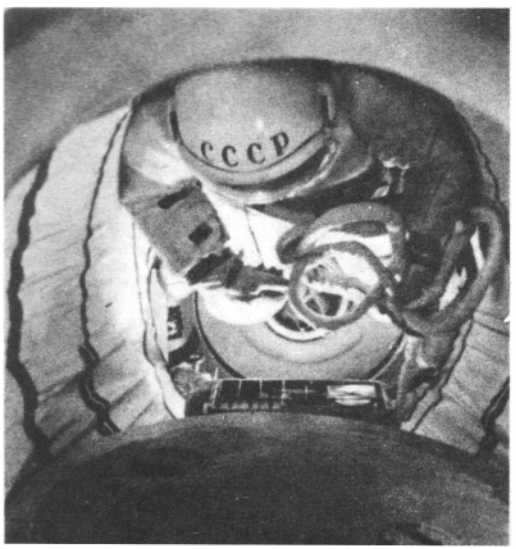
flights were made. For the first ten flights the crew members were V. M. Komarov, G. T. Beregovoi, V. A. Shatalov, B. V. Volynov, A. S. Yeliseyev, Y. V. Khrunov, G. S. Shonin, V. N. Kubasov, A. V. Filipchenko, V. N. Volkov, V. V. Gorbatko, A. G. Nikolayev, V. I. Sevastyanov, N. N. Rukavishnikov, G. T. Dobrovolsky and V. I. Patsayev.

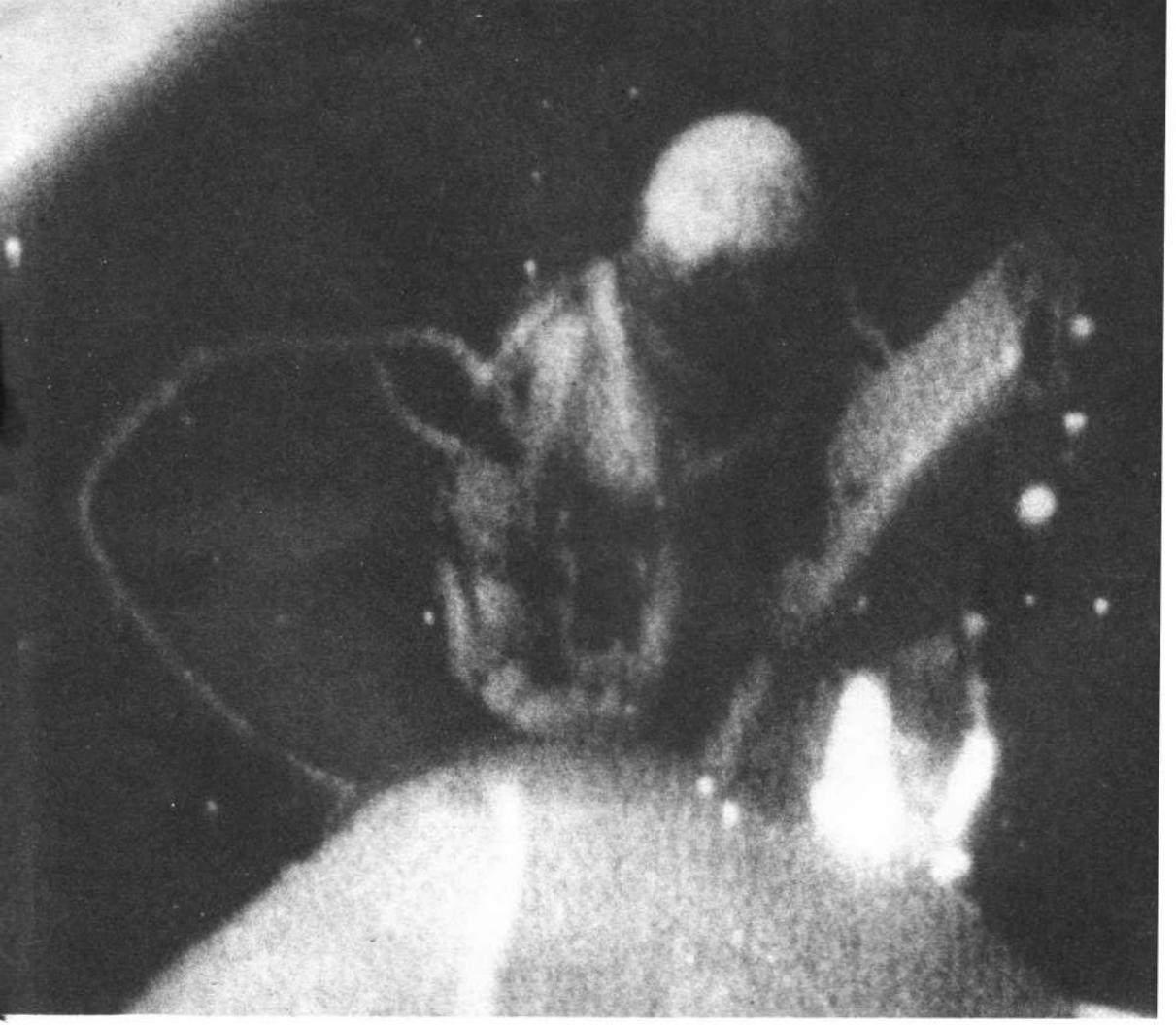
During the *Soyuz-1* to *Soyuz-10* series of flights the spaceship was thoroughly tested and perfected as an autonomous orbital laboratory and a transport vehicle; extensive manoeuvres were performed in solo and group flights; methods of mutual search, approach and docking of spaceships were tried out and practised; different types of docking devices were tested; the first experimental orbital station was established and worked successfully; the transference of two cosmonauts from one ship to another through open space was effected; a manned ship stayed aloft for eighteen days; various advanced instruments and systems were flight-tested, and experiments were conducted in welding metals in space. At the same time an extensive programme of study of near space, the atmosphere and geological and geographical objects on the Earth and bio-medical research were carried out.

On June 6, 1971 *Soyuz-11* took off carrying the first orbital station crew, Commander Grigori Dobrovolsky, Flight Engineer Vladislav Volkov and Test Engineer Viktor Patsayev. The next day the spaceship docked with the orbital station *Salyut* which the cosmonauts entered through a tunnel hatch. Thus there began to functio the world's first manned orbital scientific station. It was fully equipped for maintaining the crew for a lengthy period and for carrying out a comprehensive programme of scientific investigations.

The *Salyut* orbital station consisted of the following principal sections: a transit compartment, a working section, and a systems compartment. The transit compartment forms part of the living quarters and is also used to conduct observations

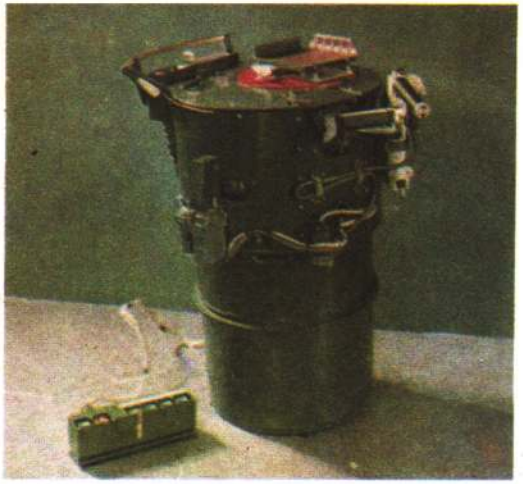
A simulated egress into outer space through the airlock of the *Voskhod* spaceship





Alexei Leonov in outer space

and experiments. Its equipment includes a docking unit for orbital link-up so that cosmonauts may move from one vehicle to another, elements of the temperature control and life-support systems, scientific instrumentation, and control panels. An automatically and manually operated tunnel hatch connects the transit compartment with the working section, which carries the main instruments and units. In this section the crewmen remain during flight manoeuvres, conduct investigations and



The *Vulkan* welding machine

Valery Kubasov in the orbital compartment of the *Soyuz* spaceship after the welding experiment in space

Assembly work in space after the docking of the *Soyuz-4* and the *Soyuz-5*

observations, have their meals, and rest. It contains stocks of water and food, life-support equipment, the radio and television systems, the controls of the on-board complex and the power supply, orientation and telemetering systems, control panels, and scientific and experimental equipment. The systems compartment consists of the engine bay, the vernier engine, the attitude control engines bay, and a system of actuators. The attitude control engines bay contains the main and back-up pitch, roll and yaw micro-rocket engines.

The transit and working compartments have about twenty portholes with fixed and removable equipment for work with orientation and navigation instruments and for photographic and visual observation.

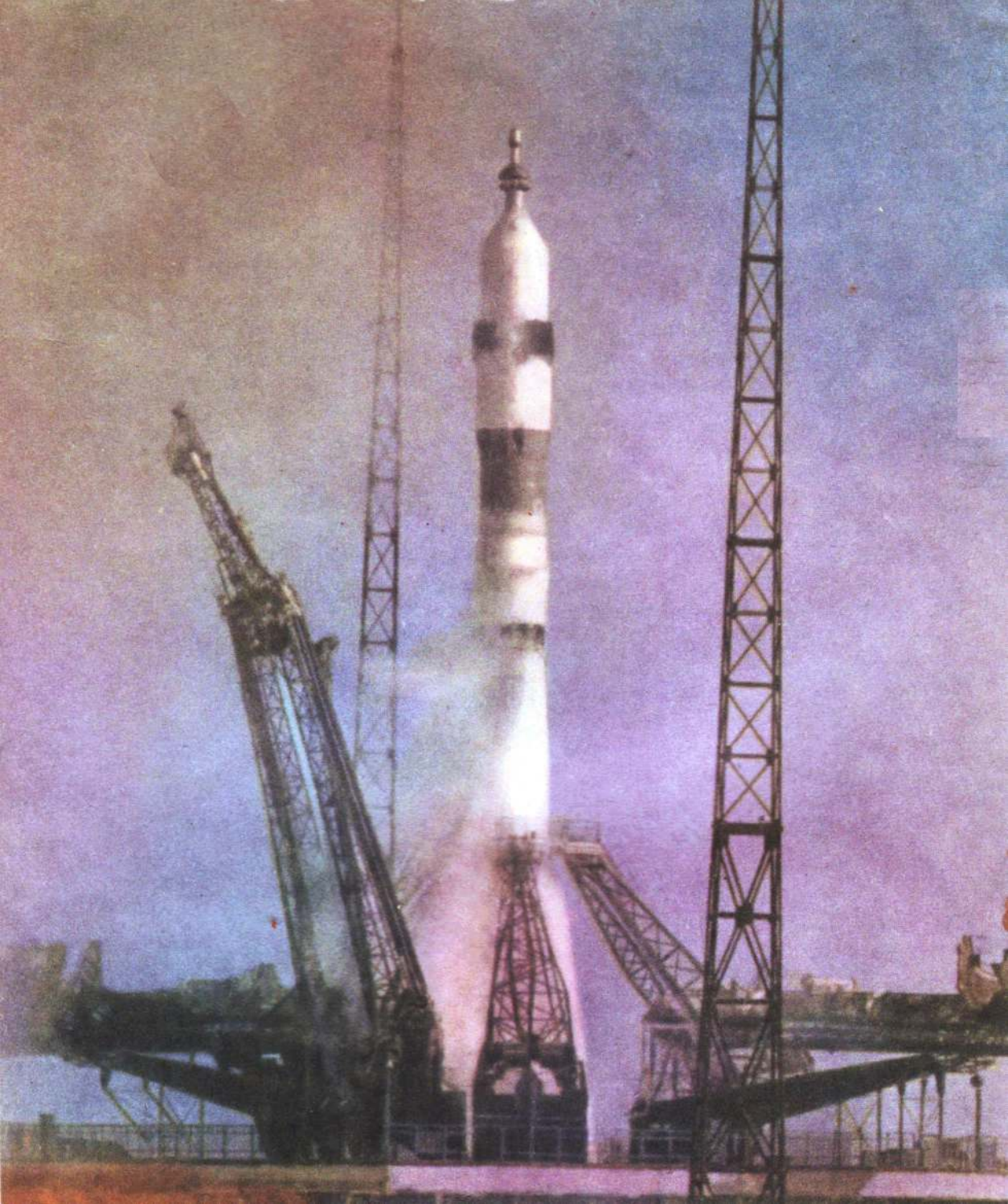
The *Salyut-Soyuz* system weighs 25 tons and is 21.4 metres long. The maximum diameter of the section is 4.15 metres and the pressurized compartments have a free volume of 100 cubic metres. The area of the panels of solar batteries is 42 square metres.

During the 23-day flight of the station a large amount of research and experimental work was undertaken by the crew. This included the study of near and deep space with the help of astrophysical instruments, the study of geological and geographical features of the Earth and, as one of the principal tasks of the flight, detailed investigation of the effect of space flight conditions on plants and living organisms.

On June 29, the flight programme fulfilled, the cosmonauts returned to the transport ship and disconnected it from the station. The next day the retro-engines were fired. The recovery capsule was already nearing the atmosphere when it suddenly became depressurized, killing the three occupants.

"Nothing comes easy to man. Not a single victory has been without sacrifice. We have begun to explore the extra-terrestrial world. But haven't even our explorations on earth been paid for with the lives of the finest people, heroes of different countries, daring sons of mankind? Some died, but new ships would leave their berths, new planes would taxi out for take-off, new expeditions would set out for forest and desert..." These words were spoken by the world's first spaceman, Yuri Gagarin.

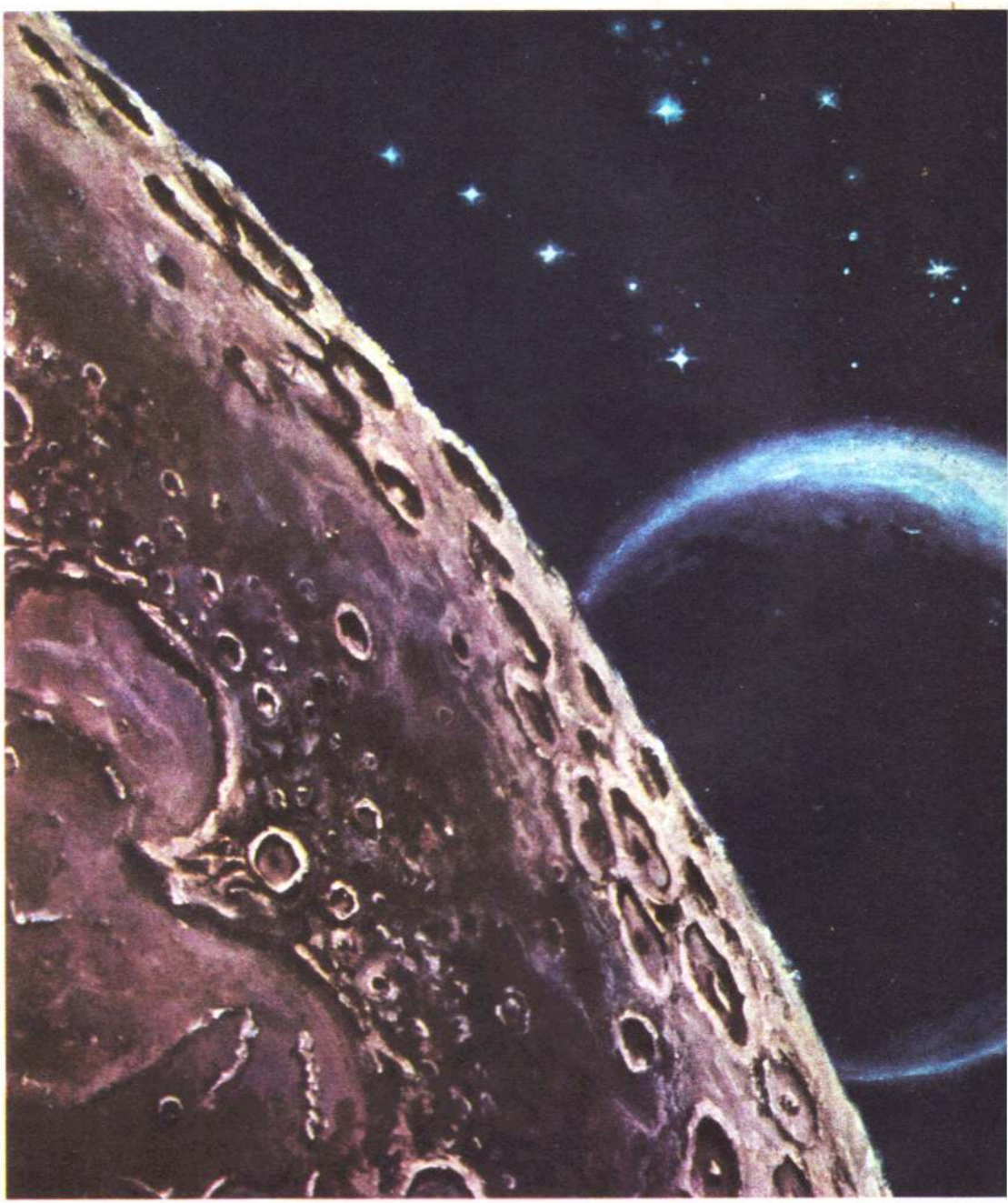
The *Salyut* tragedy cannot arrest the progress of space engineering, nor can it discourage man from exploring the Cosmos to unravel the mysteries of the Universe.

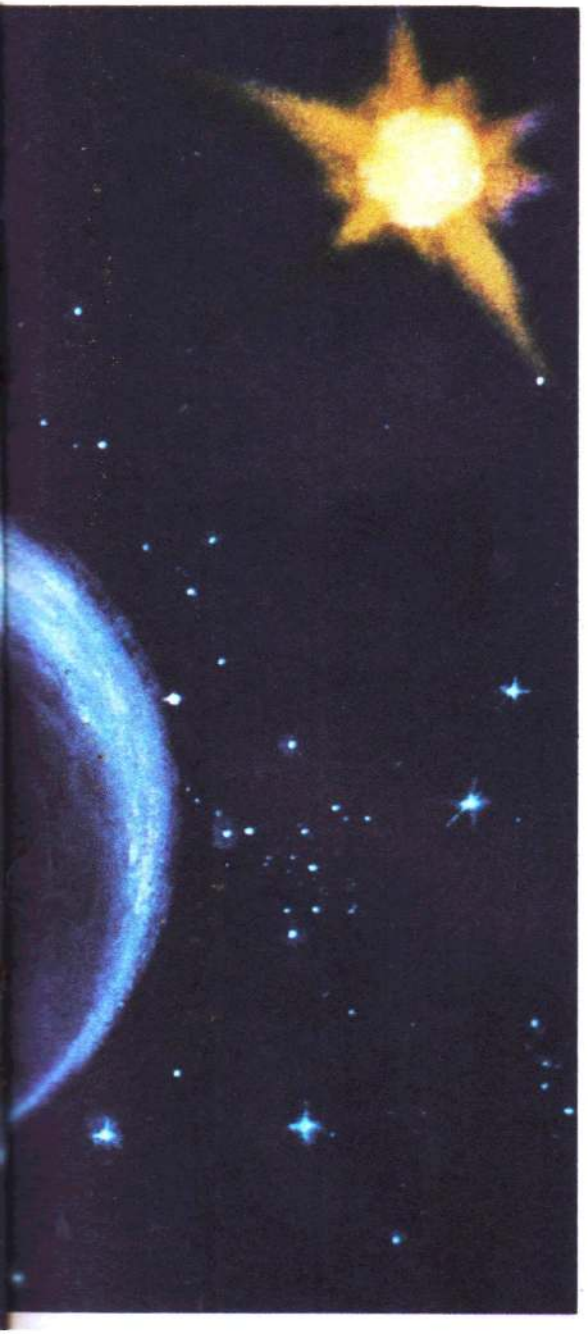


The *Soyuz* carrier rocket before launching

The first experimental orbiting station

Soviet cosmonauts Georgi Dobrovolsky, Victor Patsayev and Vladislav Volkov inside the *Soyuz* spaceship

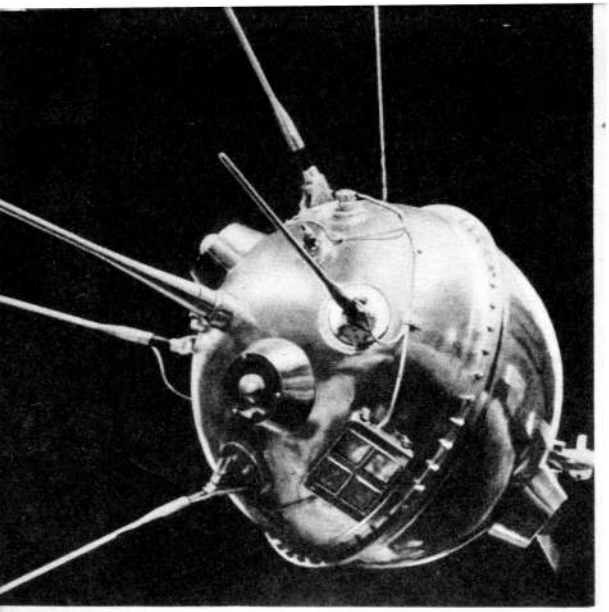




AUTOMATIC INTERPLANETARY STATIONS TO INVESTIGATE THE MOON

A year after the launching of the first artificial satellite of the Earth, conjectures were being made as to when man would make his first space flight, and the attention of scientists was already turned to our natural satellite, the Moon.

On January 2, 1959, the world's first automatic interplanetary station, *Luna-1,* took off from the Soviet Union, reached escape velocity and, 34 hours later, flew past the moon to become the first artificial planet. On its way to the moon *Luna-1* released a sodium cloud to form an artificial comet which could be observed with optical instruments. Measurements taken by instruments aboard the station yielded new data on the Earth's radiation belts and interplanetary space.

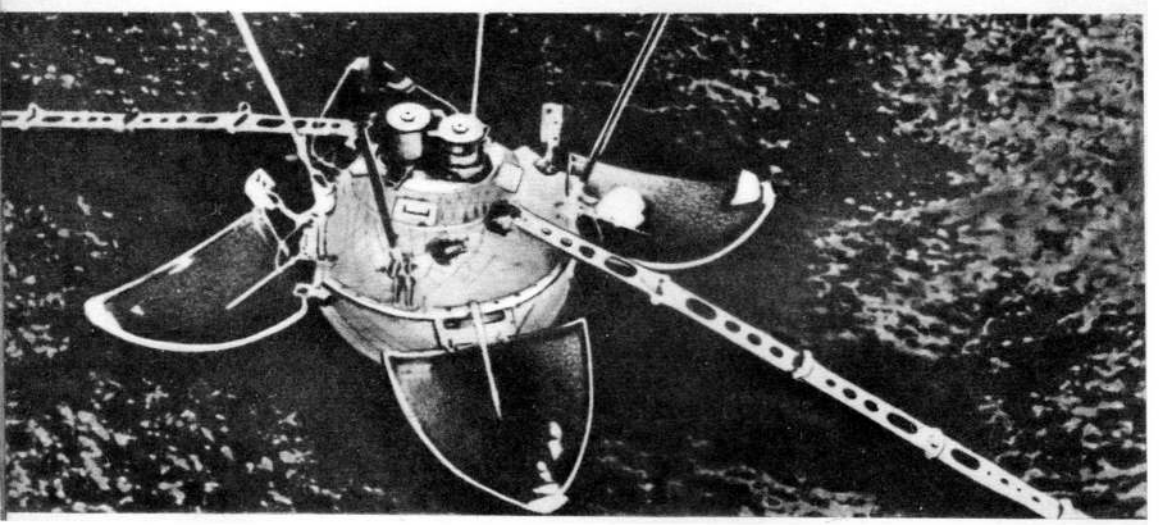


The *Luna-1* automated probe.

Luna-2 launched on September 12, succeeded in reaching the surface of the moon. Information obtained by the second lunar probe confirmed the absence of any appreciable magnetic field radiation belt around the Moon.

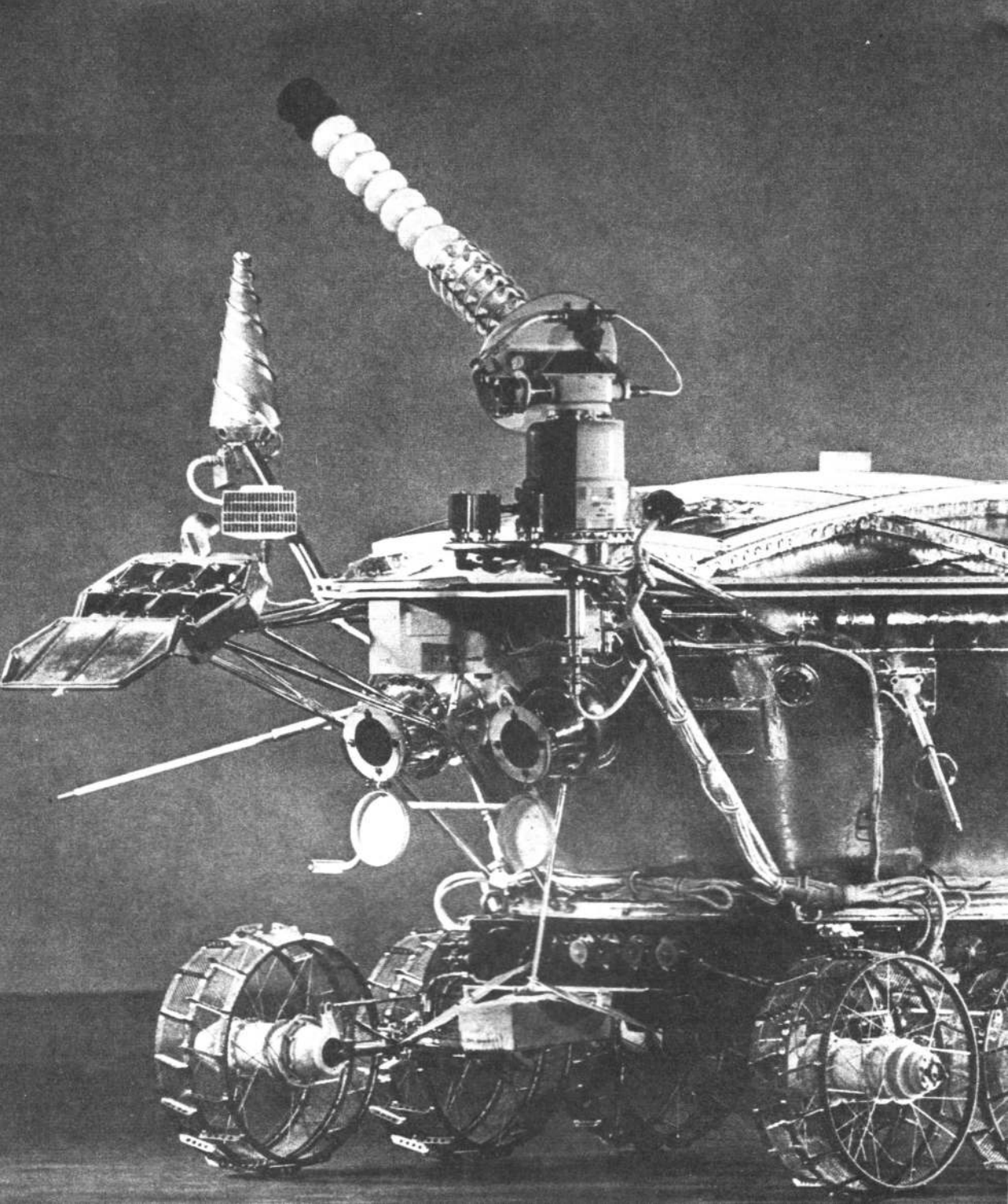
October 4 marked the launching of *Luna-3*, which created a sensation by curving behind the moon and photographing its hidden side. On October 7, from a distance of 60,000 to 70,000 kilometres from the Moon, it started photographing its reverse side. The film was processed aboard the station and the pictures transmitted to the Earth, thus satisfying the age-old curiosity of astronomers.

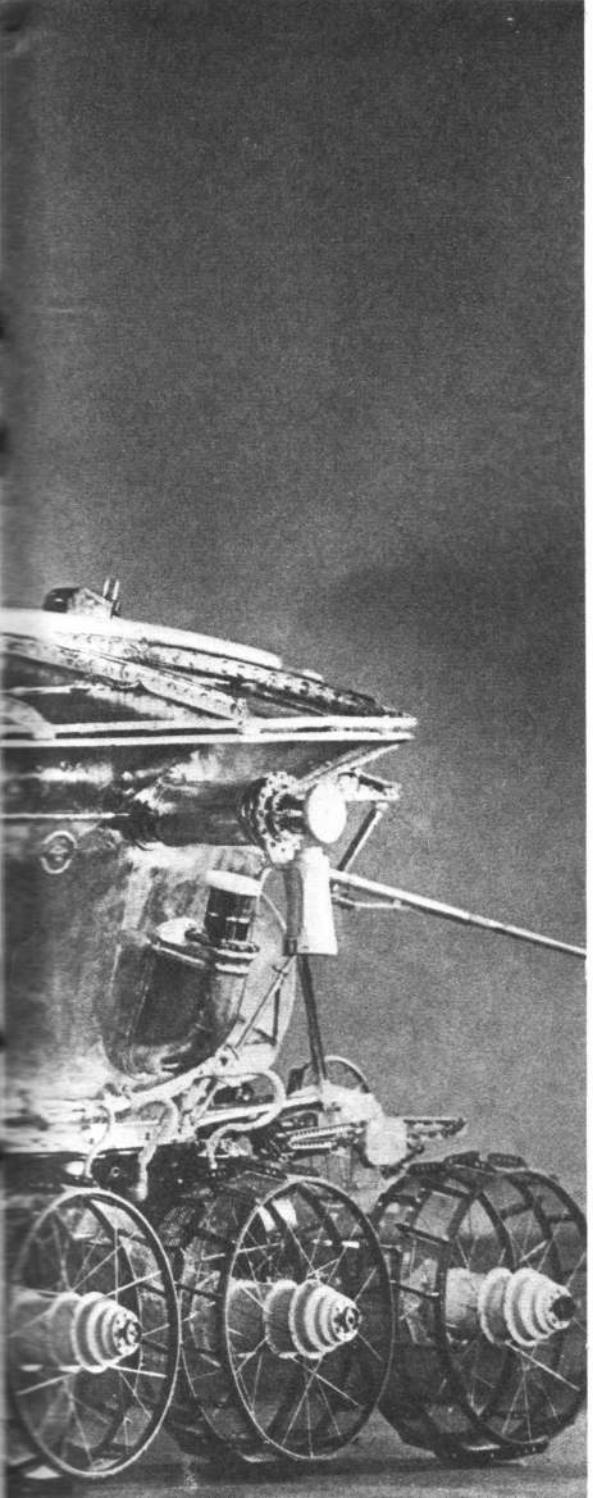
The flights of *Luna-4* to *Luna-8* which



The *Luna-13* probe

A picture taken by the *Zond-7* probe, showing the Earth and part of lunar surface





followed in 1963—65, pursued the aim of making a more detailed study of the Moon and its environs and developing a soft-landing system. With this series experience was gained in mid-course, approach and landing control and valuable scientific information was obtained.

February 3, 1966 witnessed the first soft-landing of an automatic craft on the Moon. The feat was accomplished by *Luna-9*, which touched down in the Ocean of Storms and transmitted three panoramic views of the moonscape. The pictures of the lunar surface thus obtained, and the soft landing, were of decisive significance for further moon shots, including manned expeditions. *Luna-9* made a start with direct experiments on the Moon, resolving the age-old scientific argument about the state of its surface.

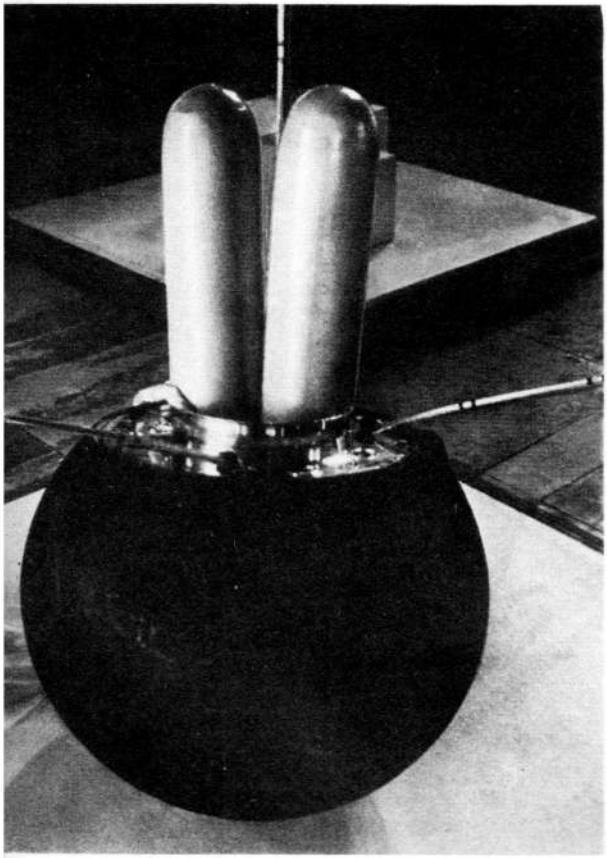
The investigations begun by *Luna-9* were later continued by *Luna-13*, which transmitted the first data on the physical and mechanical properties of superficial lunar rock and pictures of the locality taken with the Sun at different elevations over the horizon.

Luna-10, launched on March 31, 1966, became the first artificial satellite of the Moon, systematically investigating its surface and circumlunar space. Its equipment, operated continuously for two

***Lunokhod-1*, the moon rover.**

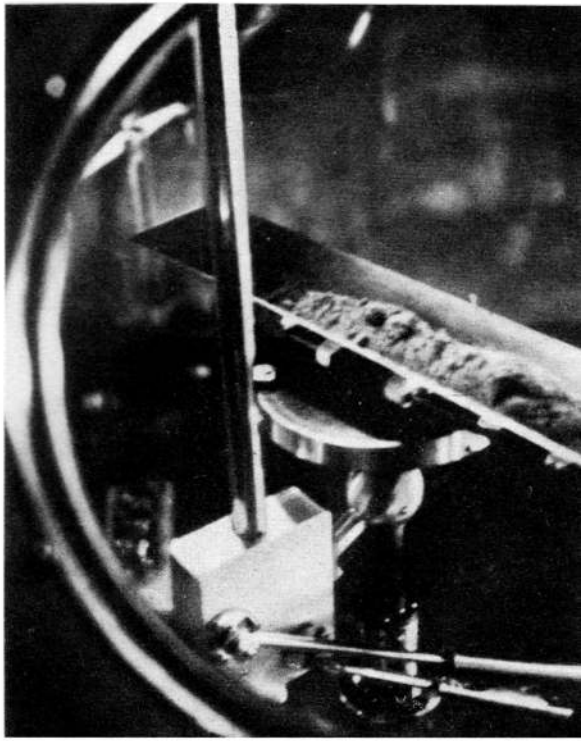
months, obtaining, indirectly, information about the chemical composition of the lunar rock surface, which proved to be much like terrestrial basalt rock.

Later, eight more probes were put in orbits around the Moon. With their aid the gamma and X-ray radiation of the lunar surface, the concentration and distribution of meteor streams and the intensity of corpuscular radiation in the vicinity of the Moon were studied, radio-astronomical observations in the long-wave band were



Recoverable module of the *Luna-20*

Lunar rock obtained by the *Luna-20* probe



carried out, sections of the lunar surface were photographed and a number of other scientific observations and experiments were conducted. The characteristics of the gravitational field of the Moon were ascertained with greater accuracy.

Luna-16 took the programme of automatic stations a big step forward. Landing in the Sea of Fertility on September 20, 1970, its automatic sampling unit proceeded to drill the lunar surface on command from Earth, take samples of rock, and seal them in a pressurized container. On September 21, after completion of the planned operations and investigations, a return rocket took off from the landing platform of the station and on September 24 delivered the samples safely to Earth, completing the first automatic sample-taking trip to the Moon.

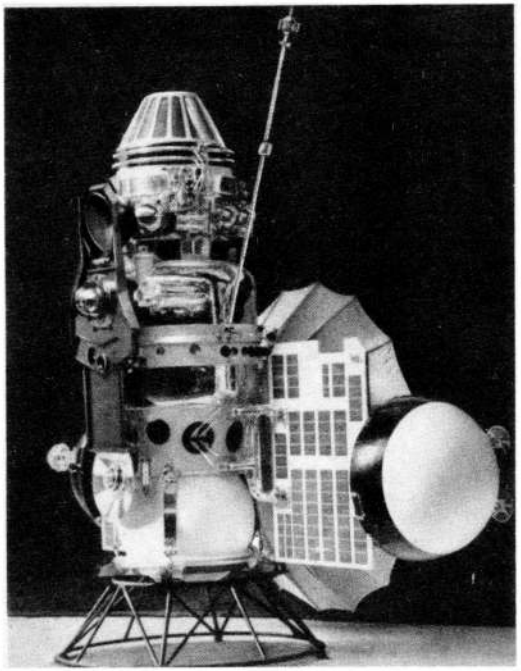
With the landing, on November 17, 1970, of *Luna-17* there began the lunar epic of the self-propelled laboratory *Lunokhod-1*, whose work was terminated almost a year later, in October 1971. Controlled from the Earth, the robot made a detailed study of 80,000 square metres of the lunar surface, measuring the density and chemical composition of lunar rock, surface radiation, the streams of protons, electrons and alpha-particles of cosmic rays bombarding the moon, and the angular distribution of low-energy protons. The *Lunokhod's* photo-TV equipment served as its eyes and at the same time transmitted to Earth panoramic views of the moonscape. The French angle reflector carried by the vehicle made possible laser surveillance of the Moon from the Earth. All told, the lunar robot travelled a distance of a little over 10 kilometres, investigated hundreds of small and large craters, determined the physical and mechanical properties of rock at more than 500 points and its chemical composition at 25 points, and transmitted more than 200 panoramic views and 20,000 photographic pictures. *Lunokhod-1* proved so successful that the principles of its design will be used again in building future planet rovers.

One more important part of the Soviet space programme is that which makes use of the *Zond* automatic stations. *Zond-3* was the first of the series to be sent to circle the Moon. It photographed the reverse side of the Moon, including regions that had not been covered by *Luna-3*, on July 20, 1965 and after developing the film transmitted the pictures back to Earth, doing so in two sessions, from distances of 2.2 and 31.5 million kilometres. Thanks to these pictures, remarkable for their high quality, a complete map of the Moon was drawn.

Between 1968 and 1970 four *Zond* probes were used to make a comprehensive study of space between the Earth and the Moon. The flight of *Zond-5* featured the first return of spacecraft from the environs of the Moon with second cosmic velocity. With *Zond-8*, a version of return with re-entry over the Northern Hemisphere was tested. In addition to the testing of various systems, *Zond* stations have been taking black-and-white and colour photographs of the Moon and the Earth and carrying out an extensive programme of scientific research in space.

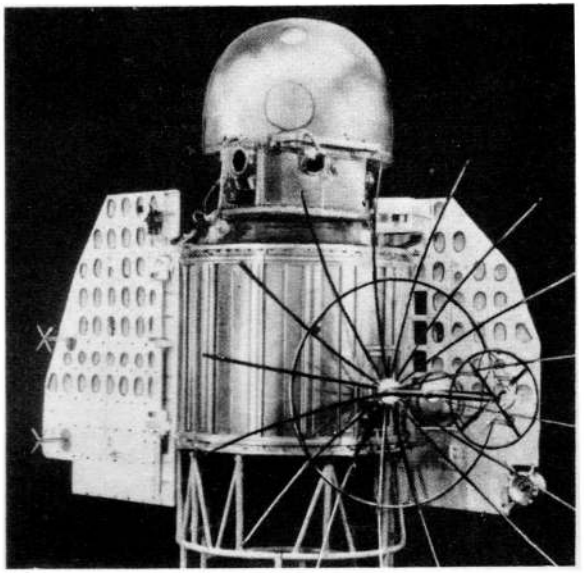
AUTOMATIC INTER-PLANETARY STATIONS TO STUDY PLANETS OF THE SOLAR SYSTEM AND INTER-PLANETARY SPACE

The Soviet space programme attaches equally great importance to the study of the nearest planets of the solar system. In the decade and a half of the space age the



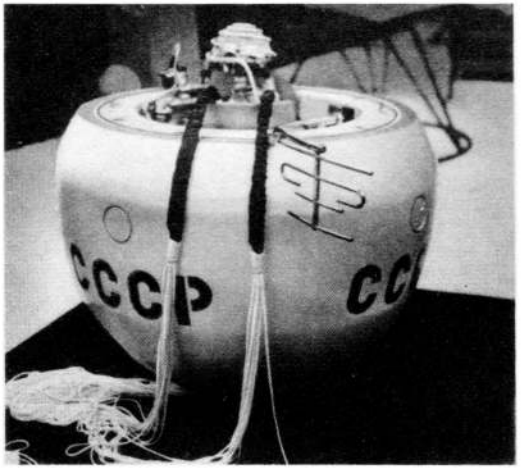
The *Venera-3* automated interplanetary probe

Soviet Union has sent more than twenty probes into deep space. The first of them besides studying interplanetary space, tested guidance systems, spaceborne equipment and long-distance radio and photo-TV communication techniques. To this group belonged the Ist, 4th and 6th *Luna* stations, the first four *Zond* probes, and the *Venera-1* and *-2* and *Mars-1* stations. During the flight of *Mars-1*, launched on November 1, 1962, radio commu-

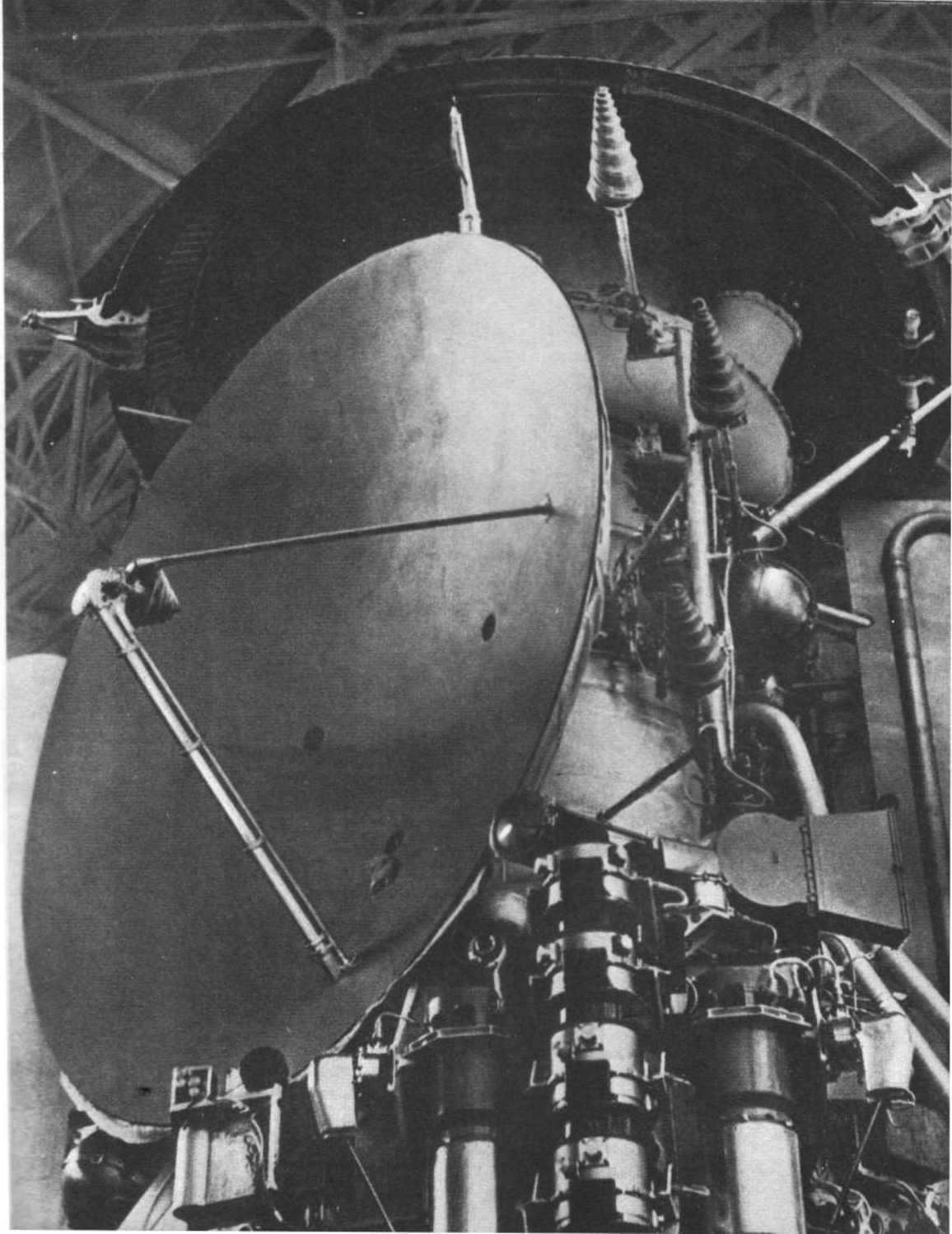


The *Mars-1* interplanetary probe

The *Venera-4* soft-landing capsule



The *Mars-3* interplanetary probe



Scientists from socialist countries discussing the joint space research programme

nication over interplanetary distances was tested. The station remained in radio contact with the Earth for a distance of 106 million kilometres. *Zond-2* (November 30, 1964) tested attitude control plasma jets. *Zond-3,* as has been mentioned, transmitted photographs taken of the far side of the Moon.

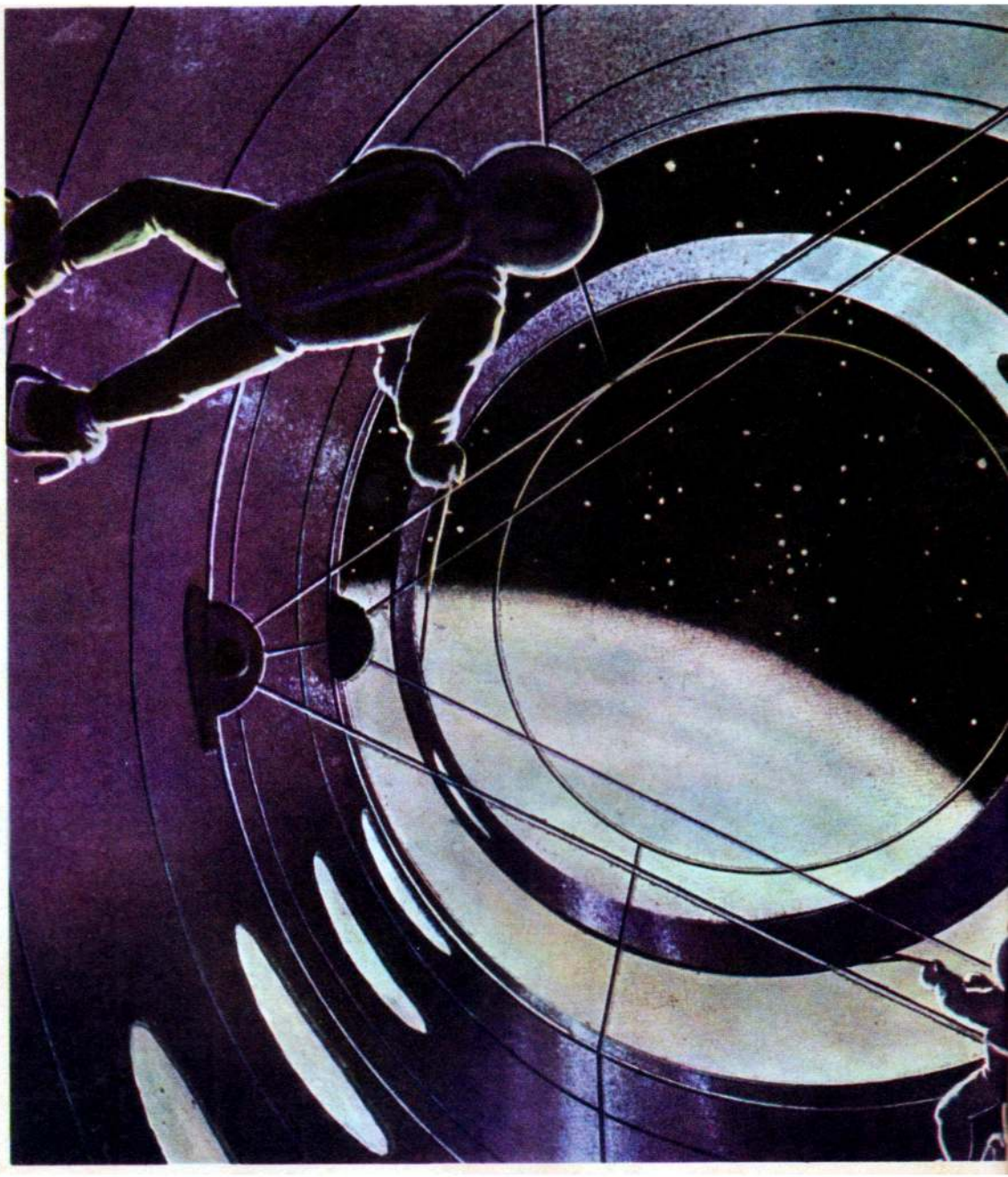
Special attention is being paid to the study of our space neighbours, Venus and Mars.

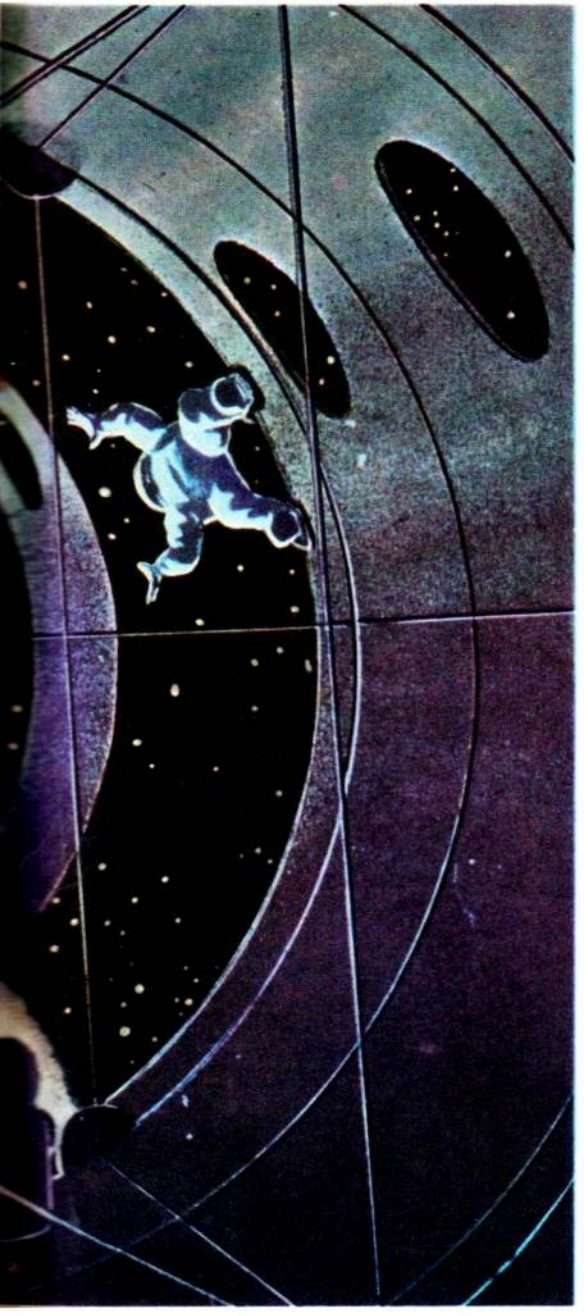
Since 1961 the Soviet Union has launched seven automatic interplanetary stations of the *Venera* series. The first two, (February 12, 1961 and November 12, 1965) flew past Venus at distances of about 100,000 and 24,000 kilometres respectively.

Venera-3 (November 16, 1965) reached the surface of the planet on March 1, 1966, delivering to it a container bearing the emblem of the Soviet Union. It thus became the world's first craft to reach another planet.

Launched on June 12, 1967, *Venera-4* travelled a distance of about 350 million kilometres and on October 18, flying at second cosmic velocity, entered the Venusian atmosphere, where an instrument package separated from it. After aerodynamic braking to a velocity of 300 metres per second a parachute system was deployed. As a result of this first slow descent in the atmosphere of another planet, which lasted an hour and a half, direct measurements of the pressure, density, temperature and composition of the atmosphere were taken. This work was continued in 1969 by *Venera-5* and *Venera-6.* On December 15, 1970, *Venera-7,* the most recent probe of this series, soft-landed on Venus and for 23 minutes transmitted directly from its surface, providing the first full information of its atmosphere.

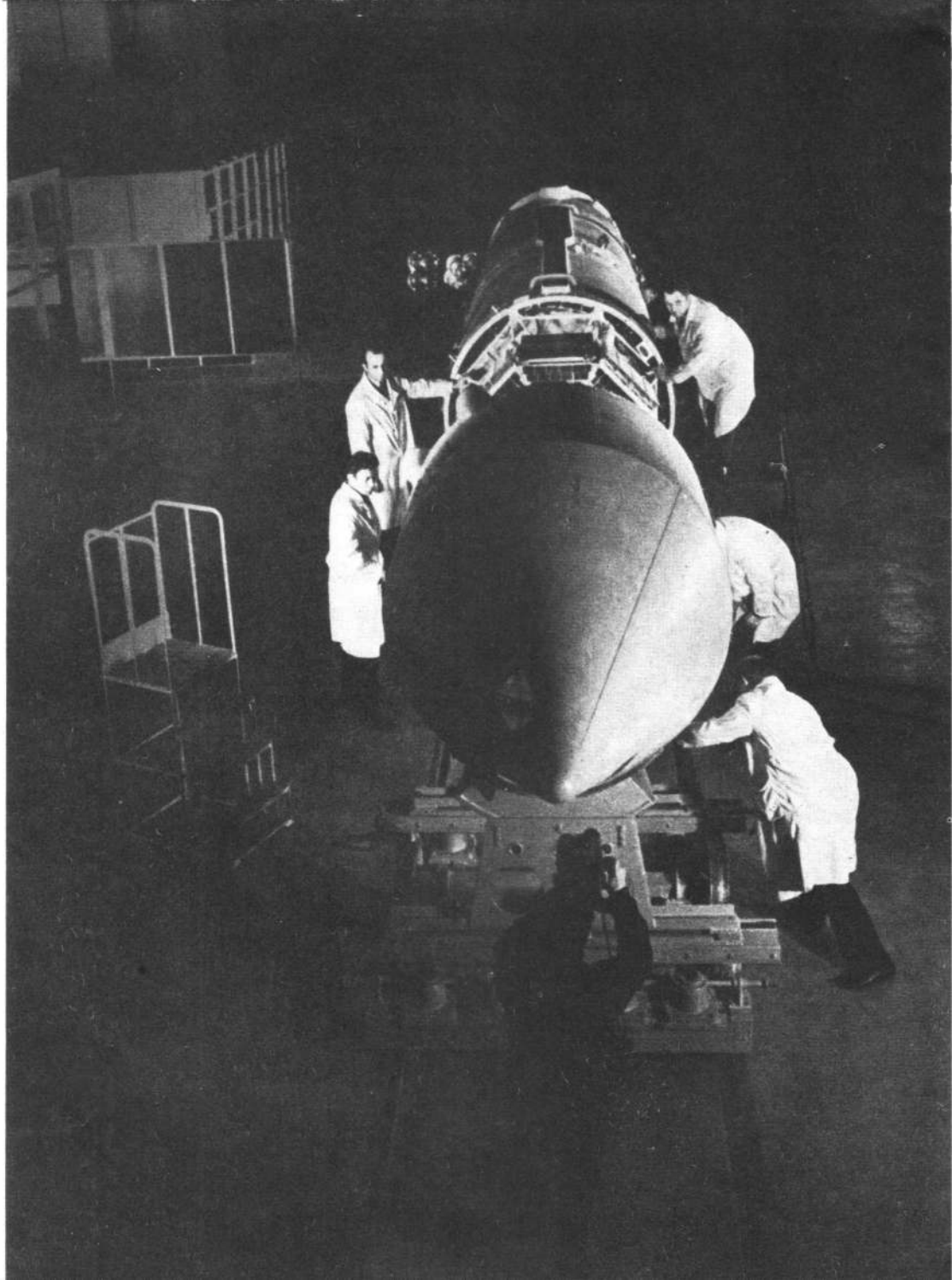
On May 19 and 28, 1971, the year when Mars came closest to Earth, two Soviet automatic stations, *Mars-2* and *Mars-3,* were sent to it. On October 27 and November 2, after travelling nearly 500 million kilometres, they reached their destination. One of them delivered to the surface of Mars a container with the Soviet emblem and the other, an instrument package. After performing a series of manoeuvres both stations became artificial satellites of Mars. They are still functioning, transmitting invaluable information about the physical properties and chemical composition of the Martian atmosphere and relaying pictures of the surface of the planet, and the results of the investigation of space near it.





INTERNATIONAL CO-OPERATION IN THE STUDY AND UTILIZATION OF OUTER SPACE

The launching, in 1957, of the world's first artificial satellite was followed with keen interest by the scientists of many countries. But the direct participation of states in joint space experiments began somewhat later.



At conferences in Moscow in 1965 and 1966, representatives of the socialist countries adopted a decision on organizing extensive co-operation in the study and utilization of space for peaceful purposes. The programme of this co-operation was adopted at a conference in Moscow in 1967. The participating countries are Bulgaria, Hungary, the German Democratic Republic, Cuba, Mongolia, Poland, Romania, the Soviet Union and Czechoslovakia. The programme provides for the investigation of the physical properties of outer space and the upper atmosphere, studies in the field of satellite-based meteorology and communications, space biology and medicine, the launching of satellites and rockets, and exchange of information.

The first satellite to be used under this programme was *Kosmos-261.* Launched on December 20, 1968, it was used to study the upper atmosphere and the nature of the aurora polaris. The experiments were continued with *Kosmos-348,* placed in orbit on June 13, 1970. As well as joint investigations conducted with Soviet-equipped satellites, since 1969 satellites and geophysical rockets have been launched carrying equipment made in other socialist countries. The first such satellite, *Interkosmos-1,* was sent up on October 14, 1969 to study ultraviolet and X-ray radiation emanating from the Sun and their impact on the upper atmosphere. The design and building of the research equipment of *Interkosmos-1* was a joint undertaking of the GDR, the Soviet Union and Czechoslovakia. On December 2, 1971 the fifth satellite of this series was launched.

Investigations are being carried out by the socialist countries with the help of geophysical rockets. One such rocket, *Vertikal-1,* was launched from a Soviet site on November 28, 1970 for the purpose of making a comprehensive study of meteoric particles, solar radiations and their absorption in the terrestrial atmosphere, and the vertical distribution of the concentration of charged particles. This vertical probing

The *Interkosmos* satellite

Space communication centre keeping track of space missions

of the upper atmosphere and circumterrestrial space was continued by a second geophysical rocket, *Vertikal-2* (August 20, 1971).

The Soviet Union and France are co-operating in the study of near space, the Moon and interplanetary space. One of the first experiments within the framework of Soviet-French co-operation was an exchange of TV programmes via the third *Molniya-1* satellite, orbited on April 25, 1966. Joint experiments in this field continue. In 1970 Soviet colour TV coverage of President Pompidou's visit to the USSR was relayed to France via a *Molniya* satellite.

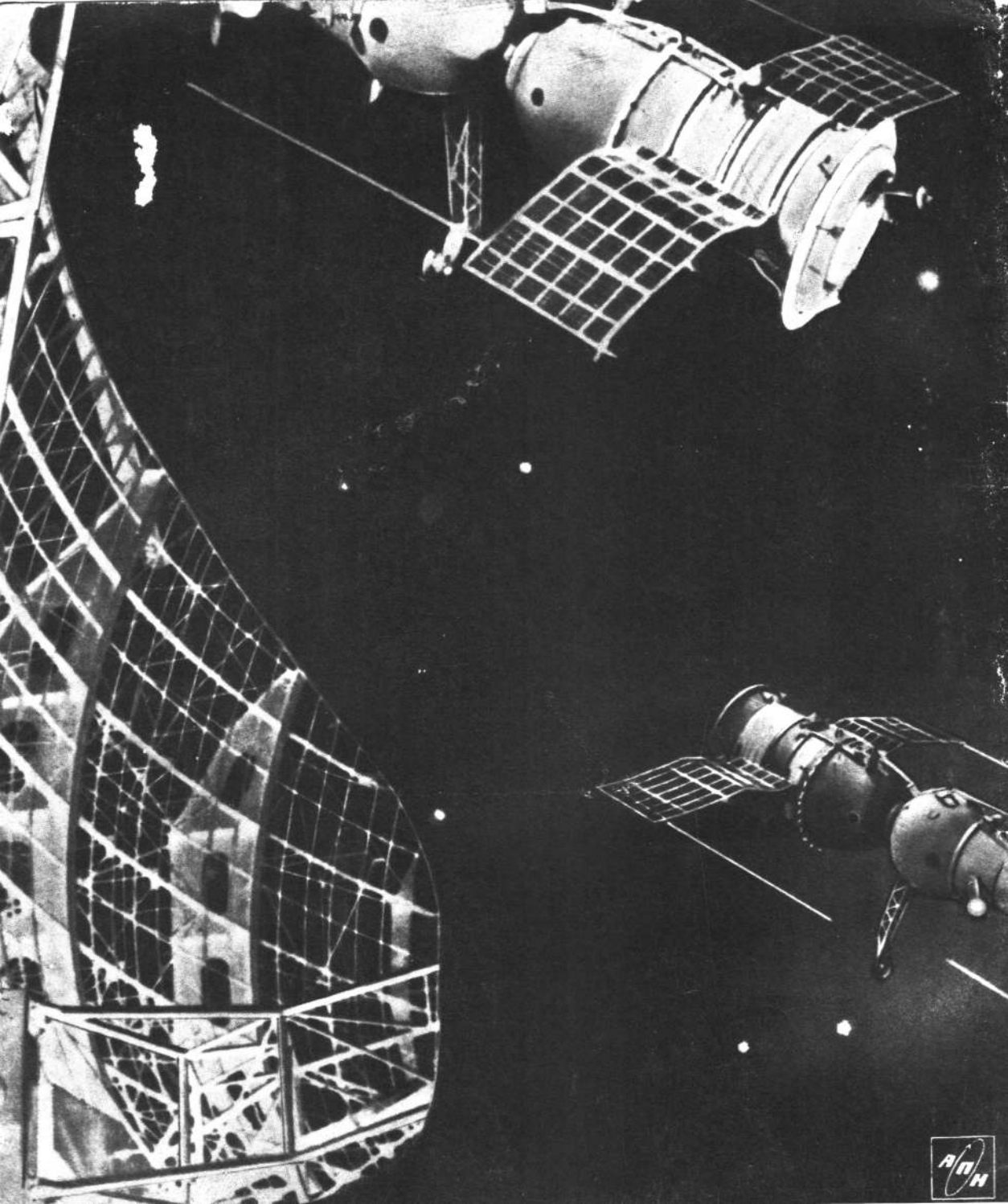
Since October 1967, under a joint programme Soviet and French scientists have been regularly launching Soviet geophysical rockets with French equipment from the *Druzhba* observatory on Hayes Island and French rockets with Soviet equipment from a site in Les Landes on the coast of the Bay of Biscay.

The French-made angle reflector mounted on the Soviet moon car enabled scientists of different countries to conduct experiments in laser surveillance of the Moon.

An experiment, designated as *Stereo*, that has yielded useful results was carried out with the help of ground astrophysical observatories and French equipment aboard the Soviet *Mars-3* interplanetary station which is now circling the red planet. On the way to Mars simultaneous registration of particle streams of the solar wind was conducted at two points: on Earth and aboard the station. Experiments under the *Stereo* programme were continued after *Mars-3* went into Martian orbit.

On December 27, 1971, also within the framework of Soviet-French co-operation, an *Oreol* satellite was launched to study physical phenomena, including aurorae polaris, in the upper atmosphere at high latitudes.

Scientists of the Soviet Union and the United States have also been co-operating in exchanging information obtained in outer space exploration and during scientific, technical and biomedical experiments. The work on unifying US and Soviet spaceship docking systems that has been going on for some time holds out the promise not only of mutual assistance in space rescue operations but also of joint experiments.

Such are the main trends and stages of Soviet study and utilization of outer space.

Советские космические исследования
на английском языке
Издательство Агентства печати Новости